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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : H04R 25/00	A1	(11) International Publication Number: WO 99/41943 (43) International Publication Date: 19 August 1999 (19.08.99)
(21) International Application Number: PCT/US99/01479 (22) International Filing Date: 11 February 1999 (11.02.99) (30) Priority Data: 09/022,552 12 February 1998 (12.02.98) US (71)(72) Applicant and Inventor: LEONARZ, Terry, R. [US/CH]; Wehntalerstrasse 178, CH-8057 Zurich (CH). (74) Agent: LEONARZ, John, E; 4611 3rd Street South, Arlington, VA 22204 (US).		(81) Designated States: CH, JP, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i>
(54) Title: LOUDSPEAKER WITH MOVABLE VIRTUAL POINT SOURCE (57) Abstract <p>A cinema sound reproduction device, to be located behind screen, which will produce a phase-coherent spheroidally shaped, superimposed wavefront which has an adjustable, determinable radius, thus possessing a stable psycho-acoustic virtual point source, which may move in a continuously variable manner from infinity to within the plane of the device, as well as in any three-dimensional axis, thereby, with the use of a positioning track and a computer, being able to be keyed in cinematic post production to visual location as displayed on a screen. The architectural sub-structure of the invention may be implemented in different ways. One such implementation may be a structure which is architecturally interchangeable with a polyhedron, and which is therefore identical for structural purposes when assembling a compound lever, which consists of a central longitudinal bar (16) and two pairs of contiguously angled bars (17, 18, 19, 20).</p> <div data-bbox="1036 1178 1317 1640"></div>		

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Loudspeaker with
Movable Virtual Point Source

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Background of the Invention

40 My invention concerns interaural time delay of a
direct sound superimposed wavefront as it is generated by
a loudspeaker array and is perceived by the ears and
brain to have a distinct spheroidal propagation and thus,
a corresponding radius vector and thus, a psychoacoustic
45 virtual point-source, hereafter referred to as an image,
in three dimensional space.

Space and source perception of human hearing in
nature, as well as with reproduced sound, depend
concurrently on at least four different parameters of
50 acoustics which are received by the left and right ears
and processed in the hearing center in the brain to
identify a sound's point-source, not only as to

55 direction, but also in rather exacting distance estimation, i.e. to find the radius vector of a given wavefront.

60 These four parameters, as long understood, may be listed as loudness (amplitude of a given soundwave); the acoustic ratio (ratio in amplitude of direct to reflected soundwaves); high frequency roll-off (absorption by the atmosphere of energy of shorter wavelengths); and finally, and most significant for image perception, time delay, or the relative difference in times of arrival of a given wavefront (at the same period of phase) at the two respective ears.

70 In order to explain the physics of creating an image one must note that time delay may be understood to exist in two regions of effect on human hearing. The proportion of the human interaural separation (approximately 15 to 21 cm.), to the audible wavelengths (which vary from approximately 1,720 cm. to 1.72 cm.) may fall into the region referred to as near-field, meaning an interaural phase-shift of time delay which is well 75 within one full cycle of a given wavelength, and which is intelligible by the brain as to degree. On the other hand, this proportion may fall into the region referred to as far field, meaning a phase-shift of time delay which is greater than 360° (one full cycle of a given wavelength), or else very near 0° in the near field which is beyond comprehension to the brain with respect to the oncoming radius vector of a direct wavefront. This far-field proportion is, however, very useful for the spatial reconstruction of reflective walls and other surrounding 80 surfaces in a recorded non-anechoic environment. This use of echo, which may be effective from 10 to 30 ms., is known as the Haas effect and is employed by the recording industry as the primary tool for building a "stereo" as well as "surround" soundstage.

90 On the other hand a direct oncoming wavefront received by the ears in an anechoic condition, i.e., with no reflective surround echo clues, may be subconsciously measured by the brain as to the phase-shift of the arrival times with respect to the tangent of the wavefront at the two ears. Although the difference may be as little as one tenth of a millisecond, in the near field region (which, with an interaural separation of 15-21 cm., lies between approximately 125 HZ (wavelength = 275 cm.) and 1500 HZ (wavelength = 23 cm.)), this delay 95 may correspond to a comprehensible amount of phase shift (that is greater than 0° and less than 360°), which may be used to triangulate the angle of the oncoming 100

105 wavefront to the head, using the following relationship:

$$\sin \theta = \frac{ct}{x}$$

where

110 θ is the arriving angle of the radius vector of the
oncoming wavefront;
c is the speed of sound;
t is the time delay; and
x is the distance between the ears.

115 Furthermore, by slightly "cocking" the head to the
first found angle, the brain may refine this estimation
in three-dimensional space, subconsciously and nearly
simultaneously, triangulating several aspects of the
wavefront, and thus, the curvature or radius, ie., with
120 a flatter wavefront signalling a more distant point-
source and more rounded wavefront signalling a nearer
point-source.

Description of the Prior Art

125 Prior art (See particularly, U.S. Patent No.
3,773,984) from Peter Walker of Quad Electroacoustics
Ltd, Huntingdon, England, provides for an arrayed
loudspeaker, marketed as the Quad ESL-63 Electrostatic
130 Loudspeaker, which involves a vibrating electrostatically
charged thin membrane which is suspended in a plane
between two like-dimensioned planar electrode grids
which, in turn, are electrically segregated into an array
of concentric annular segments surrounding a central
circular section.

135 A mono signal drives the central section with no
delay and then, in the fashion of a transmission-line
loudspeaker (a parallel line of capacitors linked with
inductance, which introduces a progressive amount of
140 delay), drives the inner most ring-segment with a given
amount of delay and then, each with an additional given
amount of delay, drives each additional ring-segment
outward from the center until the outer most ring-segment
has been activated.

145 Thus, the superimposed wavefront generated by the
Walker device propagates in a substantially spherical
pattern which has a fixed radius and therefore may be
perceived to describe an image which occupies a fixed and
150 stable point in three-dimensional space, approximately
two meters behind the loudspeaker device.

155 My invention, with the guidance of data on a positioning track and a computer processor achieves the creation of a stable image at a point in three-dimensional space at an arbitrarily chosen location behind (and including the plane of) the device and then provides means for shifting the location to any other arbitrary location behind the device.

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Summary of the Invention

165 A cinema sound reproduction device is described which when fed by an ordinary monaural input will produce a phase coherent spheroidally shaped wavefront which may be perceived by the listener as having a distinct image at an apparent point in three dimensional space, which is positioned some variable distance and direction behind the actual position of said device.

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The architectural sub-structure of this invention may be implemented in different ways. One such implementation may be an articulated compound spheroidal hinge construction of multiple sixteen-sided polyhedra composed of only equilateral triangles of identical size. Each hinged polyhedron, in turn, may serve as a platform for the mounting of one or more identical lower-midrange conventional loudspeakers. All of the loudspeakers in the array are simultaneously driven in phase, producing wavefront elements which superimpose upon one another to form a combined, or superimposed, wavefront which is heard by an observer to emanate from a source point on the central axis of the array of loudspeakers, such that the distance of the source point is dependent upon the configuration of the articulated spheroidal hinge. The loudspeakers are arrayed in a spheroidal section which has one and only one focal point, and the sound from the loudspeakers in that spheroidal configuration appears to emanate from that focal point.

180

185 Alternatively the architectural sub-structure of this invention may be a fixed array of identical lower-midrange loudspeakers, sufficient in number to form a single center loudspeaker, plus other surrounding groups of loudspeakers, more or less concentric to the center loudspeaker, utilizing a calculated delay for each individual loudspeaker.

190

200 In this case, a processor executes mono signals which are fed to the center loudspeaker at minimum delay and then with progressive, calculated delays, successively to each loudspeaker toward and including the outermost ones.

205 In either form of architectural sub-structure, a
phase-coherent superimposed spheroidal wavefront produced
by said individual loudspeakers may be varied with
respect to radius in a continuous way to define a
predetermined apparent point in space as the virtual
210 point source, or image, of the wavefront, and then, when
the radius is varied, a different apparent point in space
becomes the new virtual point source.

215 This is a psychoacoustic image. It may be seen (or
heard) to be the radius of the spheroidal wavefront. It
may be located anywhere behind said device from infinity
to within the plane of the device.

220 The perceived position of the image, whether
stationary or in motion, may be made to correspond with
the visual spatial location or movements of cinematic
characters and/or objects on the cinema screen to be
perceived by a viewer to emit a given sound. This may be
accomplished in cinematic post production with a
synchronized positioning track affixed directly onto the
225 film.

230 Also, the lateral position of an image need not
necessarily be centered on said device. In the case of
the articulated compound spheroidal hinge variant, the
device may be made simply to tilt obliquely with respect
to the plane of the screen, and then the image will
correspondingly be heard to move laterally, and/or
vertically, in accordance with the movement of the
central axis of the speaker array.

235 With the fixed-array variant of my invention, the
signal may be regulated by a computing processor to
choose any predetermined point within the array as the
center and consequently to feed surrounding groups of
240 loudspeakers within the array with calculated
progressively delayed signals until the outermost group
or segment, as needed to emulate the desired sound
wavefront. This shifts the apparent source position of
the image laterally and/or vertically in accordance with
245 calculations based upon the predetermined source point in
three-dimensional space.

250 The actual calculation is fairly straightforward.
A sound wavefront emanating from an arbitrarily
predetermined point in space expands from that point
spherically at the speed of sound. The three-space
location of all of the points along the sphere at any
instant of time can be calculated given the instant in
time at which a sound may be thought to have emanated
255 from the virtual source point, and the elapsed time

associated with the desired wavefront. Emulating that sound wavefront from a different point in space with a group of speakers is done by letting each speaker contribute an element to the emulating wavefront at the appropriate time so that the totality of the contributed elements superimpose upon one another to form the desired wavefront. To emulate that hypothetical original sound wavefront from an array of speakers, one calculates the respective delays necessary at each of the individual array speakers for that speaker's contribution to the emulated wavefront.

As may be seen with reference to Figs. 19 and 19a, from some arbitrary point "p" in space behind a planar array of speakers, a line is extended to the nearest point "a" in the plane of an array of speakers (to assume a planar array is convenient for calculation, but not necessary for practice of the invention). It may be seen that a sound wavefront from "p" would pass first at the point "a" in that array. Therefore, the delay for a speaker at "a" would be zero. With respect to the delay "delta t" for activation of a speaker "B" at a point "b" in the planar array, it may be seen that the points "p," "a," and "b" form a right triangle such that the distance "pb" is the hypotenuse and "pa" is, with respect to the angle "bpa," the adjacent side. Thus, the relationship of "pb" to "pa" is the secant of the angle "bpa." So, if the time taken for the sound originating at "p" to reach the nearest point in the array "a" is one, then secant "bpa" minus one, divided by the speed of sound, gives the delay "delta t" for the speaker at "b."

$$\delta t = \sec bpa - \frac{1}{c}$$

Thus, to emulate a sound wavefront from "p," it is only necessary to calculate the respective "delta t"s for each speaker in the array, and activate each at its appointed time. If "p" changes, all the calculations are done again for the new "p" and a different set of activation instructions is dispatched to the respective speakers.

Of course, mounting my compound variable-radius hinge speaker device in a universal mount for rotation about both vertical and lateral axes, automatically emulates a sound wavefront from a virtual point on the central axis of the compound variable radius device, located at a distance down that axis which is determined

305 by the degree of curvature, i.e., convexity, of the
loudspeaker configuration, when all of the speakers are
activated in phase. Using servo motors to control the
rotations of the universal mount and the curvature or
convexity of the hinge device, allows for automatic
310 operation and swift movement of the device from
configuration for emulation of a sound wavefront from a
first virtual point to configuration for sound from a
second virtual point.

315 Supplying the necessary data for a full system
utilizing a device or devices described in this invention
may be accomplished by printing the positioning data in
a digitized form directly onto the film, or by means of
an external device carrying the sound source-point data
to drive the loudspeakers by some synchronized means to
320 correspond with the action on the film. From this data,
all calculations can be made and activation signals
provided to each respective speaker as necessary to
emulate each respective wavefront as necessary to follow
the visual spatial location as perceived on the screen.
325

Description of the Drawings

- 330 Fig. 1 is a blank of a sixteen sided polyhedron, with
(1-15) being vertices of identical equilateral
triangles.
- 335 Fig. 2 shows how the blank is folded to form the
polyhedron unit, with broken lines indicating
"valleys" and solid lines forming "ridges."
- 340 Fig. 3 shows three successive views (a,b,c) in
elevation at 45° intervals of the polyhedron
unit as it rotates about the longitudinal axis
defined by (4+10), (3+9+15).
- 345 Fig. 4 shows three views (a,b,c) in plan of the
polyhedron unit in Fig. 3.
- 350 Fig. 5 shows three successive views (a,b,c) in
elevation at 45° intervals of a rigid crossbar
structural unit which may be alternatively
used in place of the polyhedron unit of Figs.
3 and 4.
- 355 Fig. 6 shows three views (a,b,c) in plan of the rigid
crossbar structure of Fig. 5.
- Fig. 7 shows five plan views of multiple assemblies
of the polyhedron units of Fig. 3, in

- (a) exploded view of 12 polyhedron units,
(b) exploded view of four units,
360 (c) exploded view of two assembled hinged groupings of four units each,
(d) exploded view of the assembled hinged grouping of eight units seen in (c), with
365 four additional units, and
(e) a fully assembled hinged grouping of twelve units, in a substantially planar configuration.
- 370 Fig. 8 shows the fully hinged grouping of twelve units seen in Fig. 7 (e), flexed in a convex configuration toward the viewer.
- 375 Fig. 9 shows seven successive views (a,b,c,d,e,f,g) in side elevation of the hinge structure in Fig 7 (e) as it flexes from an extreme convex configuration, Fig. 9 (a), through a planar state, Fig 9 (d), and on to an extreme concave configuration, Fig 9 (g).
- 380 Fig. 10 shows hinging detail for joinder of hinging edges of polyhedron units, and how control levers may be connected.
- 385 Fig. 11 is a frame from a cinematic film.
- Fig. 11a is a diagram of the scene in Fig. 11.
- 390 Fig. 12 is a plan diagram of the scene in Fig. 11.
- Fig. 13 shows three successive diagrammatic perspective views, respectively, of a virtual point source, the hinged assembly of
395 polyhedron units with loudspeakers mounted thereon, and a superimposed phase-coherent spherical sound wavefront emanating from the loudspeakers.
- 400 Fig. 14 is a side view, partially cut away, and partially exploded, of a configuration control mechanism for a twelve-unit assembly of polyhedrons, with loudspeakers mounted thereon, with an enlarged section in Fig. 14a.
- 405 Fig. 15 is a top view of the configuration control mechanism of Fig. 14, with an enlarged section

in Fig. 15a.

- 410 Fig. 16 is a loudspeaker array formed from a hinged assembly of 12 polyhedron units.
- 415 Fig. 17 is a side view diagram of the loudspeaker array of Fig. 16 showing a virtual point source, the array and a superimposed phase coherent wavefront.
- 420 Fig. 18 shows a front view of a fixed planar array of loudspeakers.
- 425 Fig. 19 is a diagram showing a virtual source, two loudspeakers from the array of Fig. 18 and control units. Fig. 19a shows a triangle formed by two speakers and a virtual point source.
- 430 Fig. 20 shows a diagrammatic plan of a hypothetical cinema with a loudspeaker array, virtual point sources and means for activating individual speakers in accordance with delay information which is recorded on the cinematic film.

Detailed Description of the Invention

435 With respect to Figs. 1-3, a structural unit in the form of a sixteen sided polyhedron may be formed from a blank as shown in Fig. 1. The structural unit is formed by folding the two edges 1-3, 13-15 toward each other
 440 along lines 4-6 and 10-12, and sealing at 1+13, 2+14, 3+15. The blank is now half as wide as when unfolded and still the same length. Now a convex end 6, 3+9+15, 12 and a concave end 4, 1+7, 10 are observed, which are sealed such that the convex end 6, 3+9+15, 12 seals as it
 445 naturally falls in place, and the concave end must be pinched together at points 5, 11 so that edges 7, 4+10, 1+13 seal at a right angle to sealed edges 6, 3+9+15, 12.

450 A resulting polyhedron as in Fig. 3 has an axis of symmetry referred to as the longitudinal axis 4+10 to 3+9+15 about which there exists at every 180 degree revolution congruity and at every 90 degree revolution there exists congruity which is reversed with respect to the axis 4+10 to 3+9+15.

455 The angle formed by that axis and each of four edges (1+13 to 4+10), (4+10 to 7), (6 to 3+9+15), and (3+9+15 to 12) is substantially 54.27° and the angle between edges (1+13 to 4+10) and (4+10 to 7) or (6 to 3+9+15) and

460 (3+9+15 to 12) is substantially 108.55° . These four edges are used for mounting hinges when the structural unit is assembled into a compound hinge.

465 There are twenty-four edges formed by sixteen facets. Four edges (5 to 2+14), (2+14 to 11), (5 to 8) and (8 to 11), are concave, or "valleys." All other edges are convex or "hills."

470 One can also form a structural unit of this invention by fastening together 12 equilateral triangles of the same size in the form shown, or such a structural unit could be carved from solid materials, or molded, vacuum-formed, or otherwise created.

475 An alternative structure which is architecturally interchangeable with a polyhedron of Fig. 3, and which is therefore identical for structural purposes when assembling a compound lever, is shown in Fig 5, which consists of a central longitudinal bar 16 and two pairs of contiguously angled bars 17, 18, and 19, 20.

480 As seen in Fig. 6, each bar pair is offset perpendicular to the other as viewed along said longitudinal bar 16. The angle within each pair is substantially 108.55° , and the angle of each bar 17, 18, 19 and 20 with said longitudinal bar is substantially 54.27° .

490 Material used for construction of said crossbar must allow for rigid joining, such as welded steel, as the bars act as hinge edges within a multiplicity of these crossbar structures in order to form my articulated compound spheroidal hinged compound lever, whereas with the polyhedron structure, structural integrity is afforded by its rigid, geometrically structured form.

495 It may be readily observed that it is feasible to construct the polygon structure with a reinforcing crossbar structure, or other skeletal structure, within the polygon, to afford greater flexibility in the choice of materials for fabrication of the polygon and to provide purchase for the mounting of hinges along the hinging surfaces.

500 Assembly of a twelve-unit compound hinge is shown in the several views of Figure 7. In Fig. 7a all twelve units are shown exploded and separated from one another, but in the correct orientation for joinder along their common hinging edges. The central four units, when fully assembled have vertices 21 which are to be assembled together to a common point 21. The leftmost two of the

central four have vertices h which are to be assembled together to form a common point h . Similarly, the rightmost two of the central four have vertices h' , which are to be assembled together to form a common point h' on the fully assembled 12-unit device. The points h and h' are drawn horizontally toward or apart from one another as part of the means for controlling the amount of excursion and configuration change of the 12-unit device.

As with the horizontal vertices h and h' , the uppermost two of the central four units have vertices v which are to be assembled together to form a common point v . Also, the lowermost two of the central four units have vertices v' which are to be assembled together to form a common point v' . The points v and v' are drawn vertically toward or apart from one another as the other part of the means for controlling the amount of excursion and configuration change of the 12-unit device.

Fig. 7b shows four units, A, B, C, and D, which are to be hinged together so that A's edge 17 is hinged to B's edge 18. B's edge 19 is hinged to D's edge 20. D's edge 18 is hinged to C's edge 17 and to complete the loop, C's edge 20 is hinged to A's edge 19.

Fig. 7c shows two four-units, ABCD and EFGH, each hinged together as shown in Fig. 7b, ready to be hinged together into an eight-unit device, by hinging E17 to C18 and F18 to D17, thus bringing the vertices 21 of units C, D, E, and F together to make a central point 21 in the eight-unit assembly.

Fig. 7d shows four additional single units I, J, K and L ready for hinged assembly to each other and to the eight-unit of Fig. 7c, such that I's edge 18 is hinged to J's edge 17, then I's edge 20 is hinged to C's edge 17 while J's edge 20 is hinged to E's edge 19. Finally K and L are hinged at K17 and L18, and then the 12-unit assembly is completed by hinging K20 to D19 and L20 to F19.

Fig. 7e shows the fully hinged/assembled 12-unit ABCDEFGHIJKL configured in a substantially planar configuration, with the points h and h' and v and v' now established by the assembly process.

Fig. 8 shows the 12-unit from above, as in Fig 7e, but reconfigured into a convex configuration with CDEF closest to the viewer and IJKL farthest away. Fig 8 may be seen to correspond to Fig. 9g if Fig. 9g were seen from below.

565 Fig. 9 is a series of seven side views of a 12-unit
of my invention as it flexes through a series of
configurations, from the fully concave in Fig. 9a,
stepwise to a substantially flat configuration in Fig.
9d, and finally to a fully convex configuration in Fig.
9g.

570 There are natural limits to the respective degrees
of concavity or convexity, which are reached,
respectively, when adjacent faces of the four central
structural units meet mechanically in the process of
575 being flexed together.

The addition of more units to a matrix of twelve, as
for example, three groups of twelve units hinged
together, may form a more complete spheroidal section,
580 however, due to mechanical interferences, the spheroidal
sections of such matrices are limited to the longer
radii.

A single group of twelve units provides
585 substantially a one-third spheroid section in extreme
concave or convex orientation.

There are a multitude of potential uses for a
compound hinge structure, as described above. Such a
590 structure may act as a platform to mount various devices
which radiate or receive energy waves, thereby affording
the ability to mechanically "focus" and enhance certain
properties of such energy waves.

595 For instance, a device may be constructed which may
propagate sound wavefronts by radiating them outward from
said device, e.g., convexly. Such a device may also
receive soundwaves in a concave orientation, from an
external sound source, providing for an adjustable phase-
600 reading microphone device. Thus, a specific point may be
physically located in space and be recorded or reproduced
through the use of digital processing of discrete phase-
coherent, superimposed sphere sections.

605 In Fig. 10 a means for hinging edges of polygons is
shown. The hinging edges 17/18/19/20 are bored through
end to end with sleeve channels 23. Fulcrum rods 24 are
inserted through the sleeve channels 23 and the
respective holes in the eyelets 25 and 26. The eyelet 25
610 is part of lever 25, four of which, as will be seen,
are used in causing flex movements of the finally
assembled variable radius device. The eyelets 25/26 are
secured to the fulcrum rods 24 by screws 27. Hinging
motion is therefore obtained by rotation of the eyelets
615 25/26 relative to the fulcrum rods 24 so that two

adjacent polyhedra are constrained to move relative to one another only through a plane which is orthogonal to the fulcrum rods 24.

620 Figs. 11, 11a and 12 depict a cinematic film frame with two persons speaking respectively from virtual point sources 28 and 30. Fig 11 is a depiction of the cinema screen 32. In Fig. 11a the same scene is related to
625 Figs. 18, 19 and 20 to show how the virtual point sources 28/30 appear in the respective contexts of a coplanar array of speakers (Fig. 18), a diagram of the locational relationship of the virtual point sources 28,30 to the coplanar array of speakers (Fig. 19), and the speaker array in a hypothetical theater (Fig. 20).

630 As best seen in Fig. 12, two actors 28, 30 appear in the field of view 32 of a camera. Radius vectors 29/31, trace the path between the actors (virtual point sources) 28/30 and the camera, and illustrate, in plan, the
635 geometry of the cinematic scene and the sound sources which appear within it.

Fig. 13 illustrates 3 successive diagrammatic views of a loudspeaker array 33 and a corresponding sound wave front 34, as it might appear with a virtual point source 28/30 far away, at virtual infinity (Fig 13a), more
640 closely located (Fig 13b) and quite near (Fig. 13c). For each one of an infinite number of distances down the central axis of a loudspeaker array mounted on a variable
645 radius hinged mount according to my invention, there is one and only one configuration of the hinged mount, and of the loudspeakers mounted thereon, which will produce individual sound waves from each speaker in the correct combination to be superimposed on one another to form a
650 single resultant sound wavefront which emulates a sound wavefront which would come from that point. The greater the degree of curvature, or convexity, of the hinged mounting structure (typically a 12-unit of my invention), the nearer a listener would perceive the virtual point
655 source to be. Conversely, the more nearly the hinged mount approaches flatness (i.e., the longer the radius of the spheroidal section of the hinged mount), the farther away the sound would appear to an observer standing in front of the mounted loudspeaker array.

660 A mounting and control mechanism for a twelve polygon unit loudspeaker mounting array is shown in Figures 14, 14a, 15 and 15a.

665 The entire apparatus is mounted by means of a geared main mounting plate 48, which holds a ball-bearing pivot 47 which is tied to a roller bearing housing 44. Mounted

670 within the roller bearing housing 44 is servo motor and pinion 49, the teeth of which are engaged with the main mounting plate gear 48. It may therefore be seen that azimuthal movement of the device around its vertical axis is achieved by activating the servo-pinion 49 to drive against the stationary geared mounting plate 48.

675 Also mounted within the roller bearing housing 44 is pinion gear assembly 45 which includes a small pinion engaged with teeth of a curved geared head 43, and further includes a larger gear which is engaged with the servo worm gear 46, which is fixed in the housing 44.
680 Thus it may be seen that activation of the servo worm 46 drives the pinion gear assembly 45 to that the small pinion, in turn, drives the gear head 43 radially guided by roller bearings which are held by the roller bearing housing 44.

685 The geared head 43 is rigidly attached to the base plate 42 with carries the loudspeaker mounting array and the mechanism by which the array curvature is controlled. Thus activation of the servo worm 46 to drive the pinion gear assembly 45 and the geared head 43, moves the entire
690 loudspeaker mounting array about its horizontal axis.

It may now be seen that movement of the central axis of the loudspeaker mounting array is under the control, in terms of elevation above or below a horizon, of the servo worm 46, and in terms of azimuth, to the left or right of a straight-ahead centered position, of the servo pinion 49. As those two servos are activated to drive the mounting array, the central axis of the array may be
695 pointed to any spot, left or right, up or down, behind the array, which includes coverage of any virtual point source of sound which one might wish to emulate.
700

Fixed upon the base plate 42 is the servo-worm assembly 41. The worm is engaged with teeth of a gear-pinion assembly 40 which is journaled into the housing plates 36. The teeth of the pinion portion of the gear-pinion assembly 40 are engaged with the sliding geared rack 39. The rack 39 is attached to guide head 38. Pins 37 which are fixed in the vertical levers 25 are slidably engaged in slots in the guide head 38. The vertical levers 25 are pivotably constrained by spindles 35 which are fixed to the housing plates 36. As previously discussed with reference to Figure 10, the levers 25 are
705 attached at their outer ends to eyelets 26 at the points of the hinged array designated v and v'.
710
715

It may therefore be seen that activation of the servo worm assembly 41 drives the gear-pinion 40 to move

720 the rack 39 and the guide head 38 so as to move the
levers 25 by their guide pins 37, to pivot about the
spindles 35, causing movement of the eyelets 26 at points
v and v' to change the curvature of the 12-unit polygon
speaker mounting array.

725 As best seen in Figs. 14a and 15a, the housing plate
36 and its attendant lever 25, spindle 35, etc., extend
below the level of the mounting plate 42, through a cut-
out 50 in the mounting plate 42.

730 Horizontal levers 25, best seen in Fig. 15, are
provided to connect (as shown in Fig. 10) with the points
h and h' of the 12 unit polygonal array. The levers 25
(h/h') are pivotably held in a bracket and counterforce
735 spring assembly 52, one end of each lever 25 (h/h') held
by the spring, and the other end of each lever 25 (h/h')
connected by the transverse cables and posts back to the
guide head 38, with consequent opposite forces applied to
horizontal levers 25 and vertical levers 25.

740 Thus the entire process of opening (toward a flatter
configuration and a longer radius) and closing (toward a
more convex configuration and a shorter radius) is
effected by activation of the servo worm 41 which drives
745 the gear-pinion assembly 40 to drive the rack 39 and
guide head 38 to cause the near ends of the levers 25
(v/v') to pivot around the spindles 35 and draw the
points v and v' (1) toward or (2) away from one another,
thereby causing the array to (1) close or (2) open,
750 forming a new and different spheroidal section which is
of, respectively (1) shorter or (2) longer radius. While
control of the curvature of the array is achieved by
controlling the points v/v', it is useful to provide a
counterforce spring to hold the points h/h' stable and
755 secure during changes in the configuration of the array,
under control of concurrent, but opposite movements of
the vertical levers 25 (v,v') and, through the transverse
cables and posts 51, the horizontal levers 25 (h/h') with
the bracket and counterforce spring 52.

760 As may now be seen in Figs. 16 and 17, a 12-unit,
hinged, polygonal array 33 of my invention, having been
positioned according to a specific predetermined
configuration through the mechanisms described above with
765 respect to Figs. 10, 14, 14a, 15 and 15a, may now, by
substantially simultaneous activation of the individual
speakers 53, produce a collection of individual sound
wavefronts 54, which superimpose upon one another to form
a new, single wavefront 34 which emulates a wavefront
770 which appears to an observer (generally somewhere in
front of the speaker assembly) to have come from a

virtual point source 28/30 located on the axis of the array 33 at a point whose distance down that axis (behind the array 33) corresponds exactly to the degree of curvature, or convexity, predetermined for the array 33.

It may be further seen that activation of the respective servos 49, 46, and 41, by appropriate control signals can drive the array 33 into any desired configuration, corresponding to any virtual point source generally behind the array 33. The physical system for electrical supply and control signals to the servos is entirely conventional and is not further detailed.

I have now established means by which, with a variable radius, spheroidal-sectioned array 33 of speakers 53, as shown in Fig. 17, a superimposed wavefront 34 can be made from the contributions of individual speakers, each providing its contribution according to a predetermined arrangement of azimuth, elevation and array curvature, which corresponds to a particular, virtual-source point in space.

Another means by which a superimposed wavefront 34 can be provided from contributions of individual speakers 53, particularly in a cinematic setting, is shown in Figs. 18, 11a, and 20. Speakers 33, seen in Figs. 18 and 20, are provided, presumably, but not necessarily, in a coplanar array. Sounds emanating, according to the story line of the film, from each of two actors, originate from virtual point sources 28, 30, seen straight-on in Fig 18, as the actors appear on-screen in Fig. 11a, and in plan view of a cinematic theater in Fig. 20. Each speaker 33 is under centralized control for individual activation at a time appropriate to the making of its individual contribution to the superimposed wavefront 34.

Control of a time-delay Δt which regulates the appropriate time for each speaker, is calculated with reference to Figs. 19 and 19a. Speakers 33, labelled a and b respectively are shown as part of the planar array shown in Figs. 18 and 20. A virtual point source 28, labelled p is directly behind the speaker a, so that a sound wavefront emanating from the point p and expanding as a regular sphere, first breaks the plane of the array 33 at the point a. Thus, speaker a should be activated just at the time when an expanding sound wavefront from p, or source point 28, would reach the point a in array 33. Activation of b (which is to say, of each other speaker at its time, in the array 33) is dependent upon the delay necessary for the expanding sound wavefront from p to pass the speaker plane at the point where b is located. Thus, viewing the points pab as a right

825 triangle, one observes that the time for activation of b
corresponds to the hypotenuse b_p while the time for
activation of a corresponds to the adjacent side (with
respect to the angle $b_p a$). If $p a$ equals one, then the
delay Δt for activation of b is $\secant b_p a$
830 (hypotenuse/adjacent) minus 1, divided by the speed of
sound, as noted above.

One notes that for convenience I have chosen p
directly behind the speaker a, which in practice is
unlikely. Thus, there would normally be a point a in the
835 speaker plane orthogonal to the point p, which would not
be central to one of the speakers 33. Hence, while no
speaker would be activated at a precise instant of the
impingement of the hypothetical sound wavefront 34 on the
plane of the array 33, each speaker's appointed
840 activation time is calculated with respect to that point
a. Hence, all speakers in the array may be thought of as
having a nonzero Δt .

Thus, activating the sound feed to each individual
845 speaker in array 33 in accordance with its respective
 Δt delay, may be seen in Fig. 20 to produce first
and second superimposed sound wavefronts 34 which
correspond respectively to wavefronts which would appear
(or be heard) to have originated respectively at virtual
850 source points 28 and 30.

In cinematic practice projectors 59 (Fig. 20)
project a scene upon a screen 32 which corresponds to a
film frame such as that shown in Fig. 11a, which contains
855 two virtual source points 28, 30. Data recorded adjacent
to the film frame is relayed to a computer 56, comprising
a positioning data track 57 and a normal sound track 58.

With respect to any particular frame the positioning
860 data track 57 provides to the computer 56 the desired
point p information and the beginning and ending times
for particular sounds. The computer 56 calculates Δt
for each speaker in the array 33 and feeds the
soundtrack signals at the appointed time to each speaker
865 in turn, thus providing superimposed wavefronts 34
coordinated with the virtual source points for each sound
and each frame in the film.

Since the film screen 32 is located directly forward
870 of the array 33, any psychoacoustic virtual point source
28, 30 may be made to correspond to a visual spatial
position as perceived on the screen.

The sound track 58 may consist of a plurality of
875 forward channels, i.e. for loudspeakers located behind

880 the screen, each corresponding to a different virtual sound source, i.e. a different point p and each being delivered to its corresponding set of speakers in the array 33 according to the respective delta t delays, as necessary to correspond to complex scenes involving multiple, and simultaneous, sounds and sources.

885 Of course, this system may also be used with a simple mono forward channel, e.g. the center channel in a Digital Dolby System 5.1, or its equivalent.

I claim:

5 1. A structural unit comprising two pairs of hinging edge members,

10 said hinging edge members defining substantially straight hinging edges, and at least extensions of said hinging edges meeting at a vertex lying on the longitudinal axis of said structural unit, and said hinging edge members having means for mounting hinge means thereon,

15 said hinging edge members being disposed at opposite ends of said structural unit along said longitudinal axis such that each pair of said hinging edges is disposed orthogonally with respect to the other of said pair of hinging edge members when viewed along said longitudinal axis,

20 means for holding said two pairs of hinging edge members in rigid juxtaposition to one another,

25 each of said hinging edges of said pair of hinging edge members being disposed at an angle of substantially 108.55° from the other hinging edge of said pair, and

each said hinging edge being disposed at an angle of substantially 54.27° from said longitudinal axis.

30

2. The structural unit of claim 1 comprising two pairs of hinging edge members disposed at opposite ends of a rigid connecting member.

35

3. The structural unit of claim 1 comprising a closed polyhedron of sixteen sides, each of said sides being an equilateral triangle.

40

4. A four unit compound lever comprising four identical structural units as in Claim 1,

45

each of said identical structural units having two hinging edge members at each end of said identical structural units,

50 one of said hinging edge members at a first end of a first one of said identical structural units, being hinged to one of said hinging edge members at a first end of a second one of said identical structural units,

55 one of said hinging edge members at the second end of said second identical structural unit being hinged to one of said hinging edge members at a first end of a third identical structural unit,

60 one of said hinging edge members at the second end of said third identical structural unit being hinged to

one of said hinging edge members at a first end of a fourth identical structural unit, and

65 one of said hinging edge members at the second end of said fourth identical structural unit being hinged to one of said hinging edge members at the second end of said first one of said identical structural units,

70 each of said first and second ends of each of said structural units having one hinged hinging member and one free hinging member.

75 5. An eight-unit compound lever comprising a first and a second four-unit compound lever of claim 4 with free hinging members of two contiguous identical structural units of said first four-unit compound lever being hinged together with free hinging members of two contiguous
80 structural units of said second four-unit compound lever,

 thus forming four mutually contiguous central identical structural units, two from said first four-unit
85 compound lever and two from said second four-unit compound lever,

 said longitudinal vertices of each of said four mutually contiguous structural units meeting at a common
90 point, with longitudinal vertices of each of the other three mutually contiguous structural units, and

 each of said four mutually contiguous structural units having three of its four hinging members hinged and
95 one of its four hinging members free.

6. A twelve-unit compound lever comprising the eight-unit compound lever of claim 5 and further comprising two sets of two identical structural units of claim 1, each of said sets of two identical structural units having a hinging edge member of a first end of a first structural unit hinged to a hinging edge member of a first end of a second structural unit, and a hinging edge member of each of the second ends of each of the two identical structural units hinged to one of said free hinging edge members of said four mutually contiguous structural units of said eight-unit compound lever.
7. A loudspeaker system for creating a superimposed sound wavefront which emulates a sound wavefront which would come from an arbitrarily chosen first particular point in space, comprising:
- mounting means,
- a plurality of individual loudspeakers disposed upon said mounting means for producing individual sound wavefronts responsive to activating signals,
- means for coordinating activation, by said activating signals, of said loudspeakers for production of individual sound wavefronts from each of said plurality of loudspeakers,
- said coordinating means including means for activating each said loudspeaker individually according to a predetermined plan based upon said first particular point in space, to produce individual sound wavefronts, said individual sound wavefronts forming a superimposed sound wavefront from said plurality of loudspeakers, and said

superimposed sound wavefront emulating a sound wavefront originating from said first particular point in space, and

135

said coordinating means further including means for modifying said predetermined plan for activating said loudspeakers for emulation of a sound wavefront originating from at least a second particular point in space.

140

8. The loudspeaker system of claim 7 wherein said mounting means includes variable radius spheroidal section apparatus for mounting individual ones of said loudspeakers, and

145

said predetermined plan includes variation of said variable radius and movement of said mounting means as necessary for emulation of said second point in space.

150

9. The loudspeaker system of claim 7 wherein said predetermined plan for activating said individual loudspeakers includes time delays for sequencing activation of each said individual loudspeaker, said time delays for each individual loudspeaker being selected according to the spatial position of said loudspeaker for activation at a time when a wavefront emanating from said speaker contributes a sound wavefront component to said superimposed sound wavefront as necessary for said superimposed wavefront to emulate a sound wavefront from said first particular point in space, and

155

160

means for recalculating said time delays for sequencing activation of each individual loudspeaker, said recalculated time delays being selected according to spatial position of said individual loudspeaker for

165

activation at a time when a wavefront emanating from said individual loudspeaker contributes a sound wavefront component to said superimposed sound wavefront as necessary for said superimposed wavefront to emulate a sound wavefront from said second particular point in space.

10. A method for emulating sound wavefronts which would emanate from arbitrary points in space, comprising the steps of:

identifying a first arbitrary point in space,
activating each of an array of individual loudspeakers to deliver an element of a wavefront which, when each of said wavefront elements is superimposed upon each other, form a superimposed wavefront corresponding to a wavefront which would emanate from said first arbitrary point in space, and

identifying a second arbitrary point in space, and
activating each of said individual loudspeakers in said array of loudspeakers to deliver an element of a wavefront which, when said elements are superimposed upon each other, form a superimposed wavefront corresponding to a wavefront which would emanate from said second arbitrary point in space.

11. The method of claim 10 wherein activation of said array of loudspeakers includes the step of arranging said loudspeakers in a first spheroid sectional pattern, said first spheroid being chosen to include a first radius which focuses upon said first arbitrary point in space, and activating each one of said array of loudspeakers substantially simultaneously to provide wavefront elements which superimpose upon one another to emulate said wavefront which would emanate from said first arbitrary point in space, and

identifying a second arbitrary point in space, and
changing said spheroid sectional pattern of
loudspeakers to a second spheroid sectional pattern
205 having a second radius which focuses on said second
arbitrary point in space, and activating each one of said
individual loudspeakers in said array of loudspeakers
substantially simultaneously to provide wavefront
elements which superimpose upon one another to emulate
210 said wavefront which would emanate from said second
arbitrary point in space.

12. The method of claim 10 wherein activation of said
loudspeakers includes the step of calculating from a
215 first particular time at which a sound might emanate from
said first arbitrary point in space, a first time delay
at which a first loudspeaker should be activated to
contribute a first wavefront element to a wavefront which
would emanate from said first arbitrary point in space at
220 said first particular time, and

the additional step of calculating from said first
particular time, a second time delay at which a second
loudspeaker should be activated to contribute a second
wavefront element to said wavefront which would emanate
225 from said first arbitrary point in space at said first
particular time, and

successive repeated additional steps of calculating
from said first particular time, additional time delays
at which additional individual loudspeakers should be
230 activated to contribute respective individual wavefront
elements from respective loudspeakers, said calculations
producing time delays for said wavefront elements to
superimpose upon one another to produce a wavefront which
would emanate from said first arbitrary point in space at
235 said first particular time, and

the step of activating each individual loudspeaker

in accordance with its respective calculated time delay to contribute its respective wavefront element for superimposing with wavefront elements contributed by each other individual loudspeaker to create a superimposed wavefront which corresponds to a wavefront which would emanate from said first arbitrary point in space at said first particular time, and

the step of identifying a second arbitrary point in space,

the step of calculating from a second particular time at which a sound might emanate from said second arbitrary point in space, a first time delay for said second arbitrary point in space, at which a first loudspeaker for said second arbitrary point in space should be activated to contribute a first wavefront element to a wavefront which would emanate from said second arbitrary point in space at said second particular time, and

the additional step of calculating from said second particular time, a second time delay for said second arbitrary point in space at which a second loudspeaker should be activated to contribute a second wavefront element to said wavefront which would emanate from said second arbitrary point in space at said second particular time, and

successive repeated additional steps of calculating from said second particular time, additional time delays at which additional individual loudspeakers should be activated to contribute respective individual wavefront elements from respective loudspeakers, said calculations producing time delays for said wavefront elements to superimpose upon one another to produce a wavefront which would emanate from said second arbitrary point in space at said second particular time, and

the step of activating each individual loudspeaker

in accordance with its respective calculated time delay to contribute its respective wavefront element for superimposing with wavefront elements contributed by each other individual loudspeaker to create a superimposed wavefront which corresponds to a wavefront which would emanate from said second arbitrary point in space at said second particular time.

13. Loudspeaker apparatus having variable virtual sound point sources for cinematic applications wherein at least first and second virtual point sources are identified with respect to first and second cinematic images projected on a cinematic screen, said first and second cinematic images being associated respectively, in context of a cinematic presentation, with first and second virtual point sound source locations behind said cinematic screen, comprising:

mounting apparatus for mounting an array of loudspeakers,

means for activating individual ones of said loudspeakers to contribute a first wavefront element to a first superimposed wavefront according to a first predetermined plan for emulating a wavefront which would have emanated from said first virtual point sound source location, and

means for further activating individual ones of said loudspeakers to contribute a second wavefront element to a second superimposed wavefront according to a second predetermined plan for emulating a wavefront which would have emanated from said second virtual point sound source location.

14. The loudspeaker apparatus of claim 13 wherein said mounting means includes variable radius spheroidal section apparatus for mounting said array of

loudspeakers, and

310 said predetermined plan includes variation of said
variable radius and movement of said mounting means as
necessary for individual ones of said array of
loudspeakers to be activated substantially simultaneously
for contributing individual wavefront components to a
first superimposed wavefront for emulation of a wavefront
which would have emanated from said first virtual point
315 sound source location, and

320 said predetermined plan further includes variation
of said variable radius and movement of said mounting
means as necessary for individual ones of said array of
loudspeakers to be activated substantially simultaneously
for contributing individual wavefront components to a
second superimposed wavefront for emulation of a
wavefront which would have emanated from said second
virtual point sound source location.

325 15. The loudspeaker apparatus of claim 13, wherein said
first predetermined plan for activating said individual
loudspeakers includes a first set of time delays for
sequencing activation of each said individual
loudspeaker, each one of said first set of time delays
330 for each individual loudspeaker being calculated
according to the spatial position of said loudspeaker for
activation at a time when a wavefront element emanating
from said loudspeaker would contribute a sound wavefront
element to said superimposed sound wavefront as necessary
335 for said superimposed wavefront to emulate a sound
wavefront from said first virtual point sound source
location, and

340 said second predetermined plan for activating said
individual loudspeakers includes a second set of time
delays for sequencing activation of each said individual
loudspeaker, each one of said second set of time delays

345 for each individual loudspeaker being calculated according to the spatial position of each said loudspeaker for activation at a time when a wavefront element emanating from said loudspeaker would contribute a sound wavefront element to said superimposed sound wavefront as necessary for said superimposed wavefront to emulate a sound wavefront from said second virtual point sound source location.

1/11

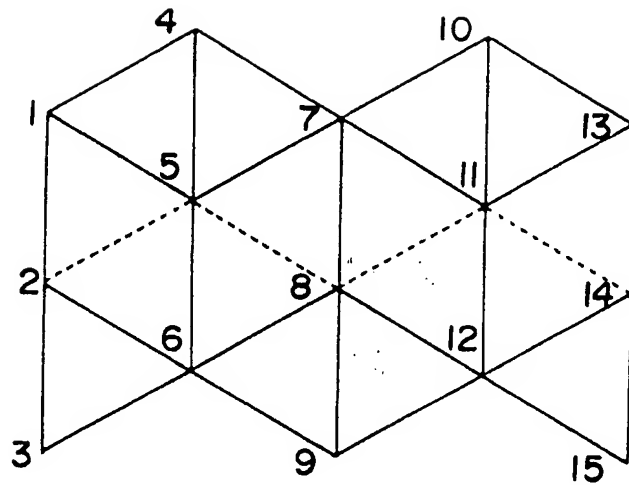


FIG. 1

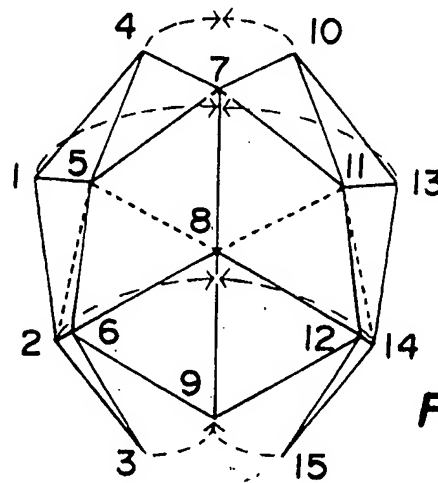


FIG. 2

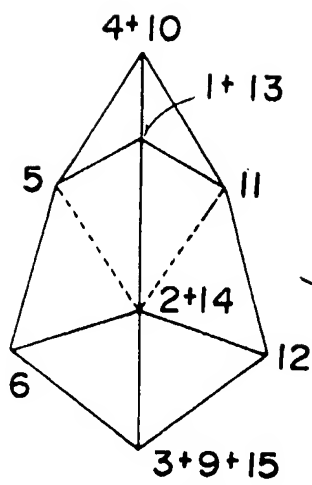


FIG. 3a

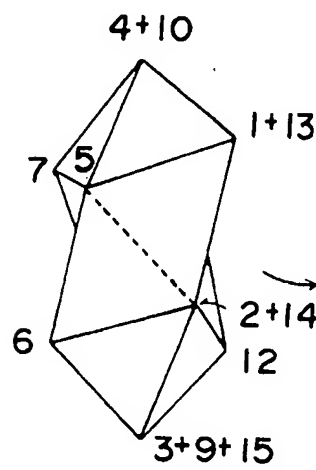


FIG. 3b

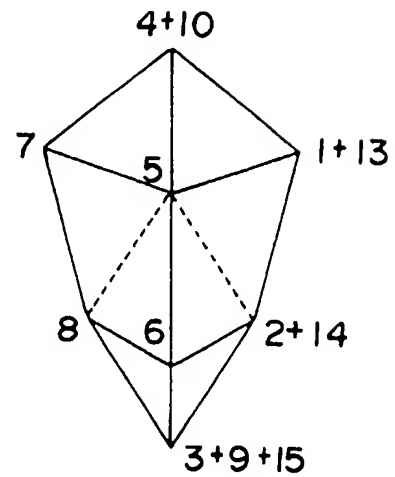


FIG. 3c

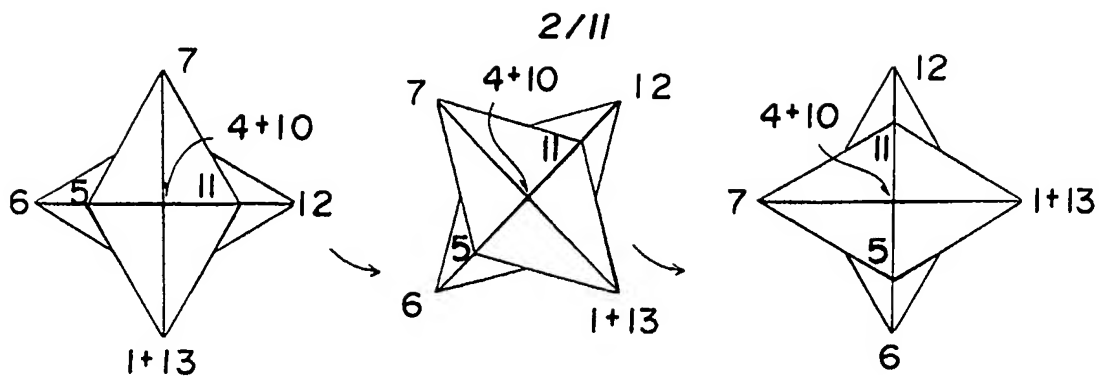


FIG. 4a

FIG. 4b

FIG. 4c

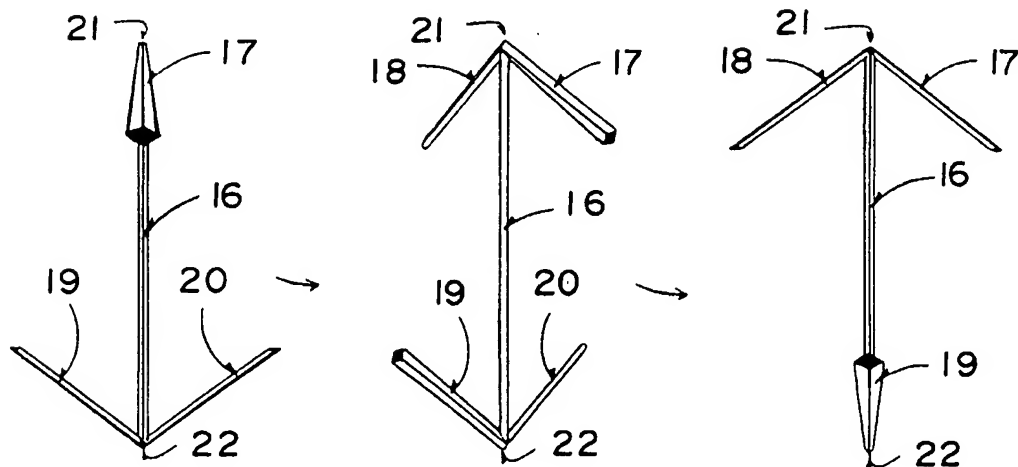


FIG. 5a

FIG. 5b

FIG. 5c

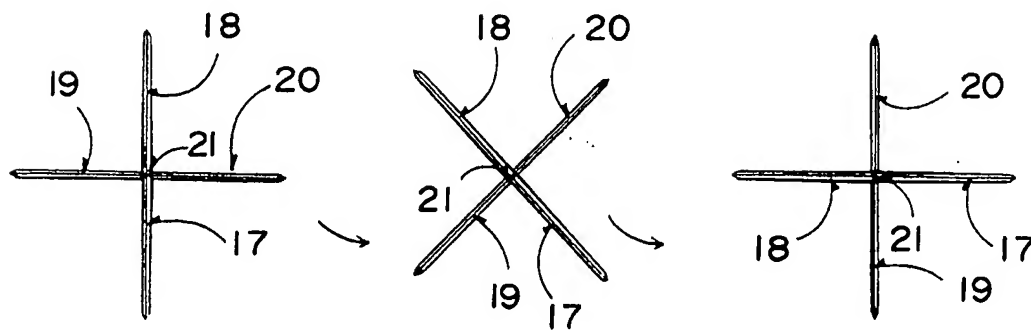


FIG. 6a

FIG. 6b

FIG. 6c

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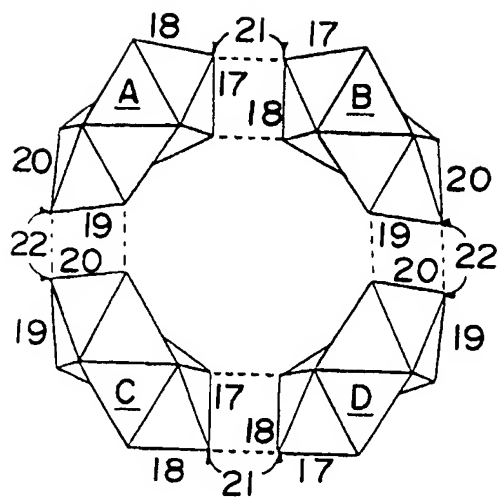


FIG. 7b

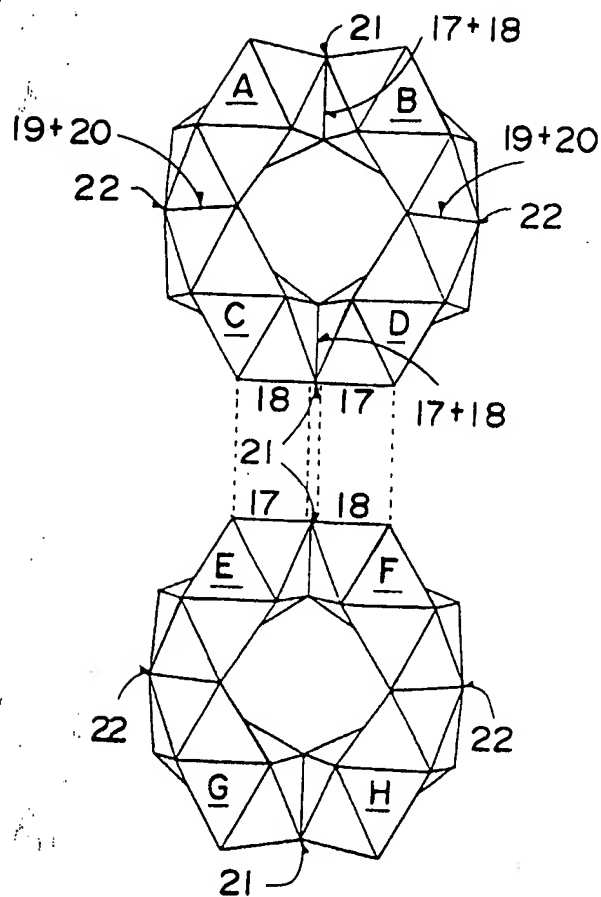


FIG. 7c

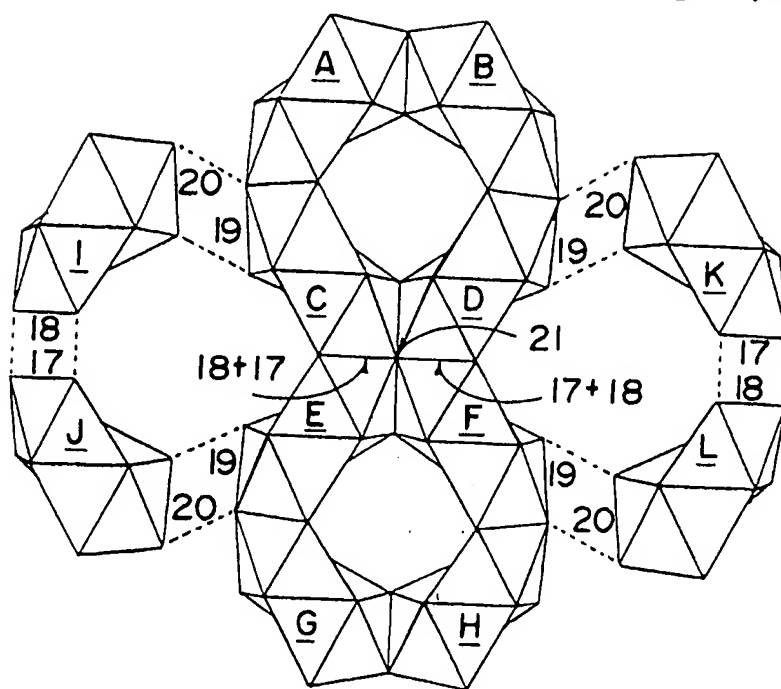


FIG. 7d

4/11

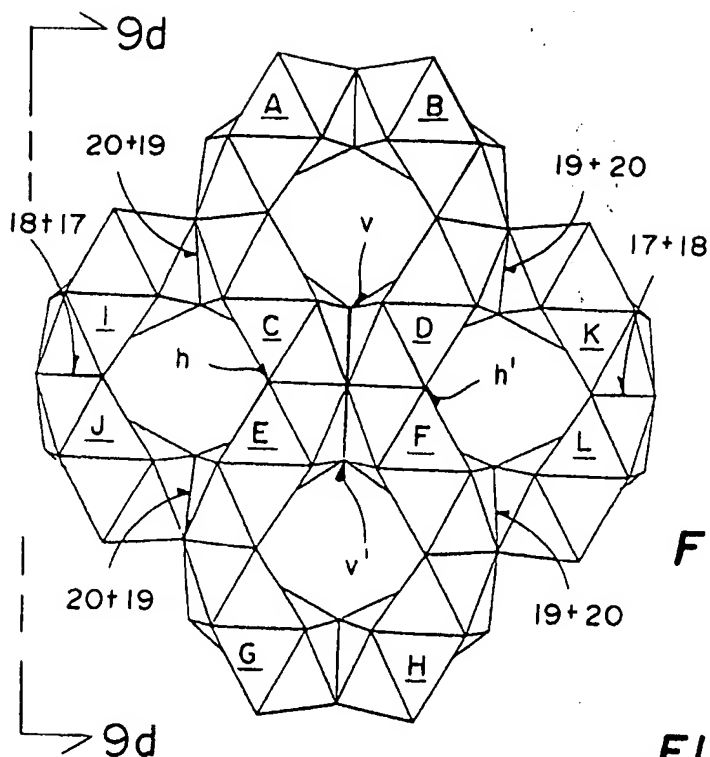


FIG. 7e

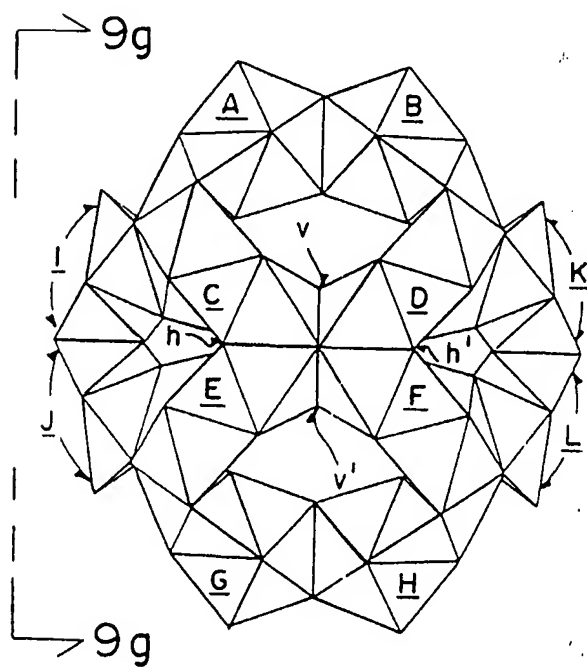


FIG. 8

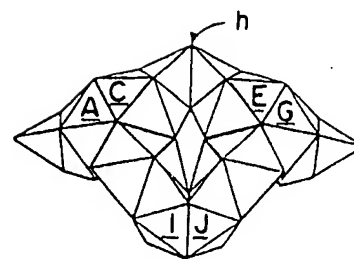


FIG. 9a

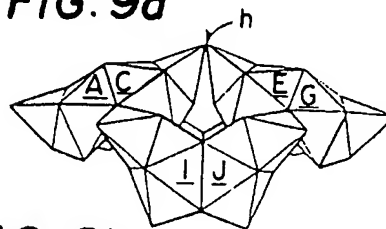


FIG. 9b

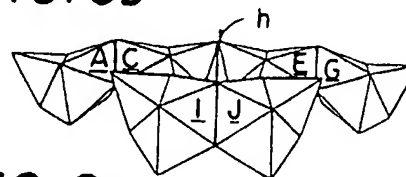


FIG. 9c

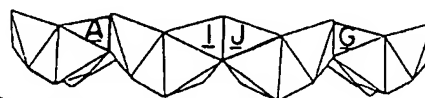


FIG. 9d

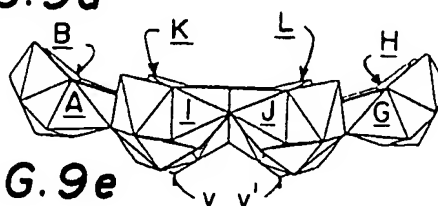


FIG. 9e

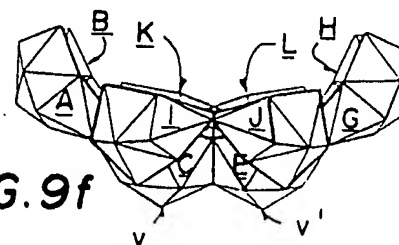


FIG. 9f

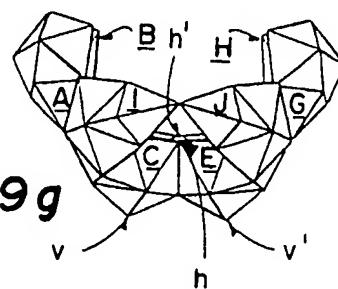
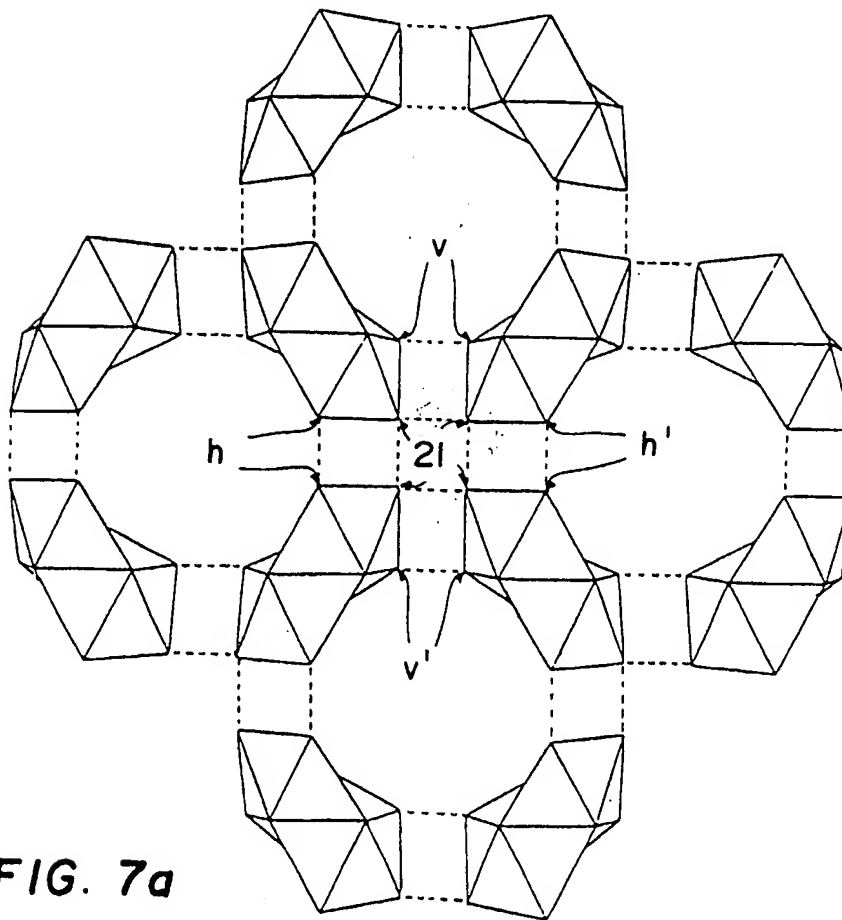
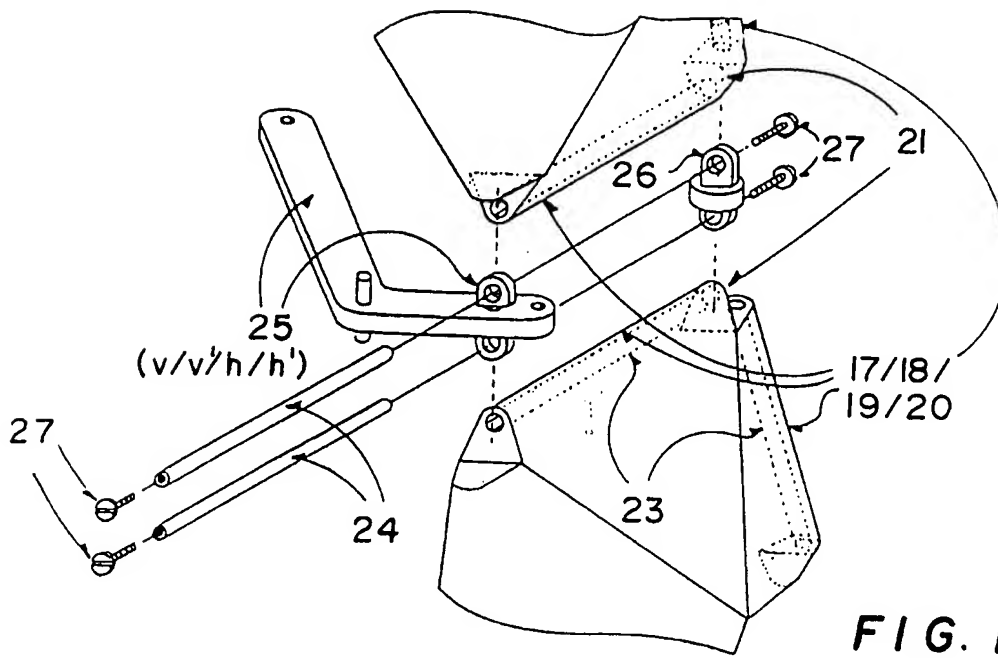


FIG. 9g

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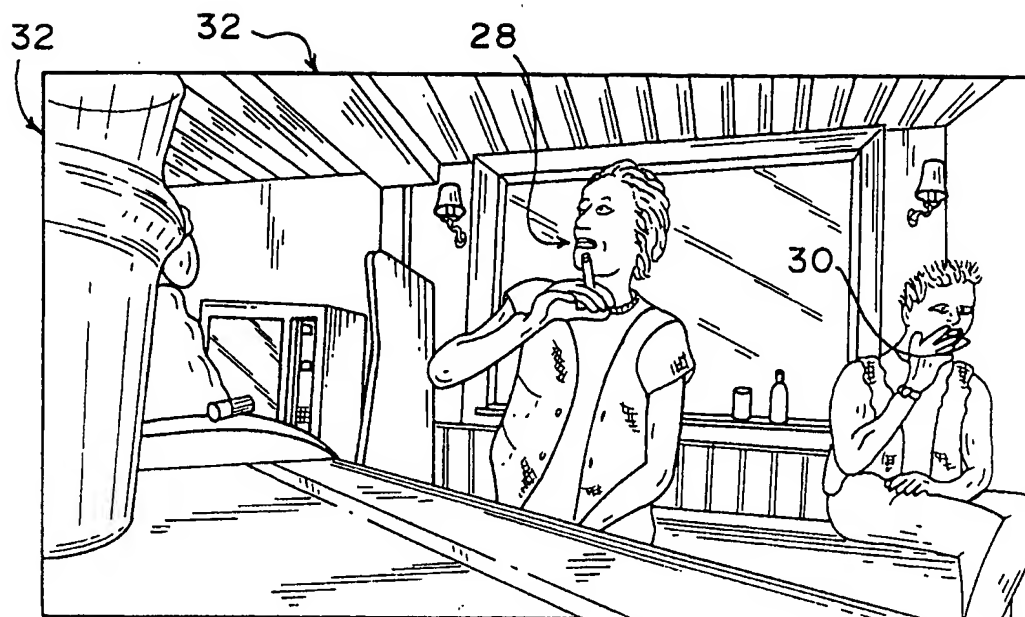


FIG. 11

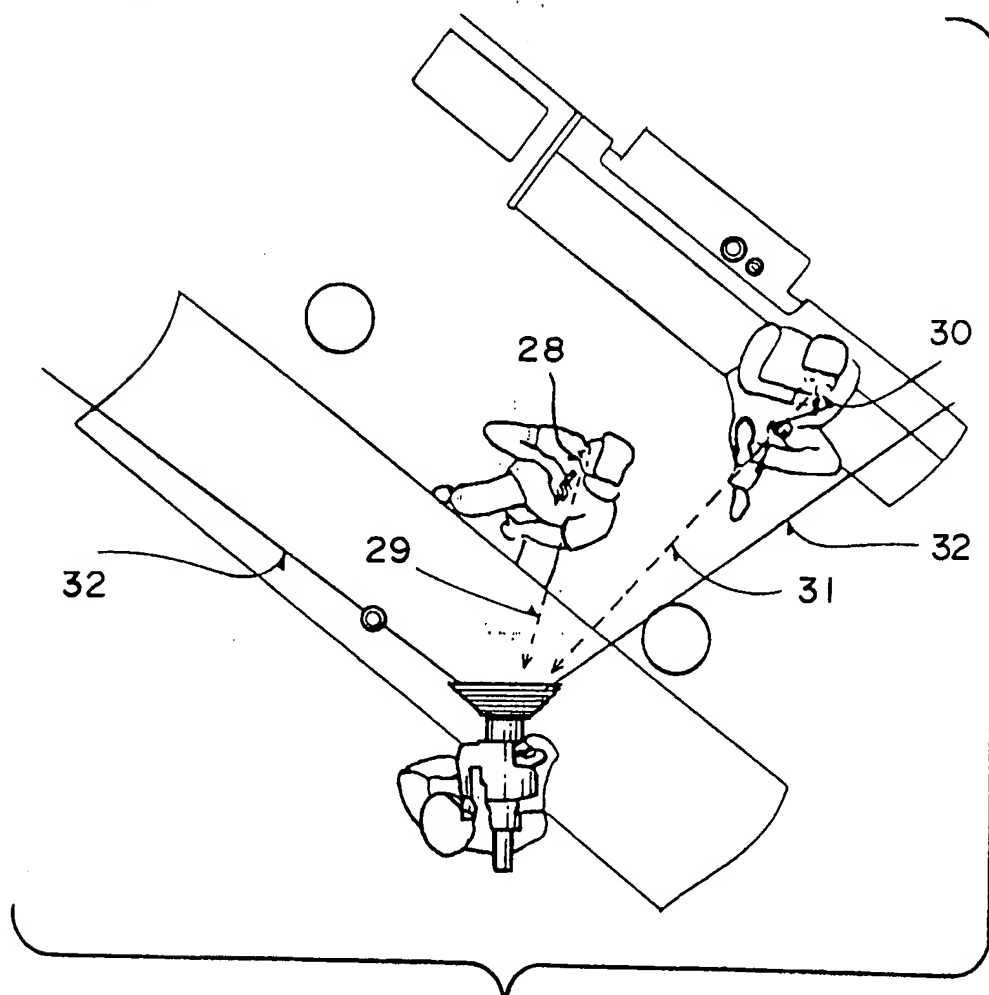


FIG. 12

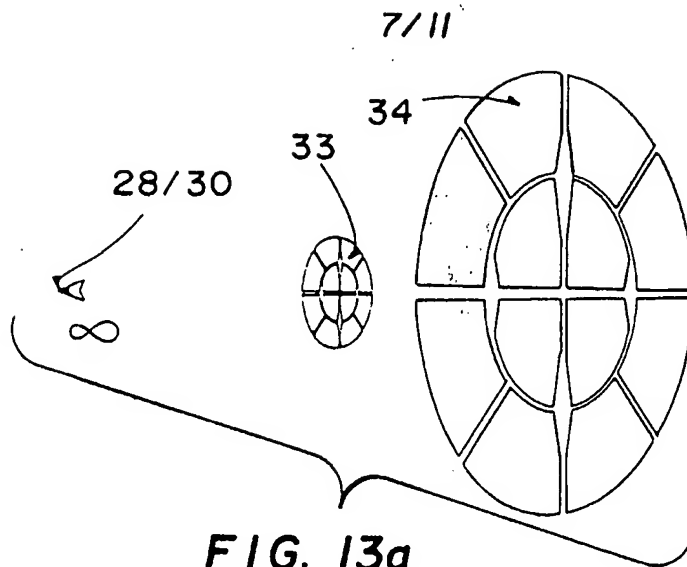


FIG. 13a

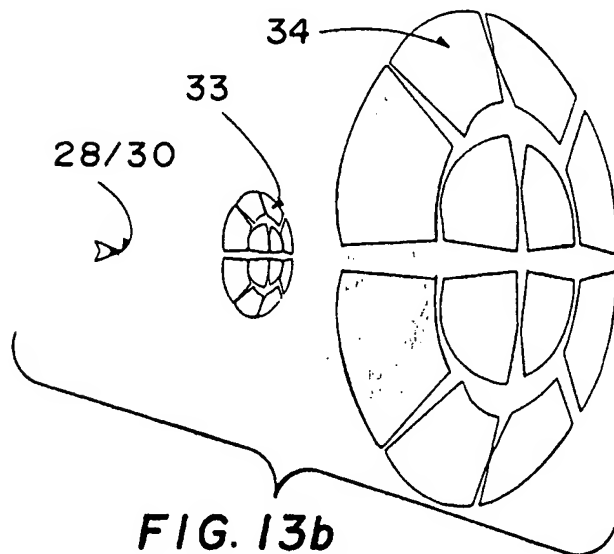


FIG. 13b

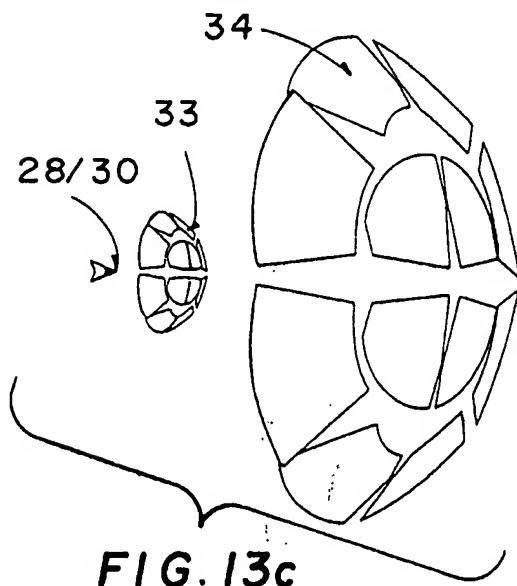


FIG. 13c

8/11

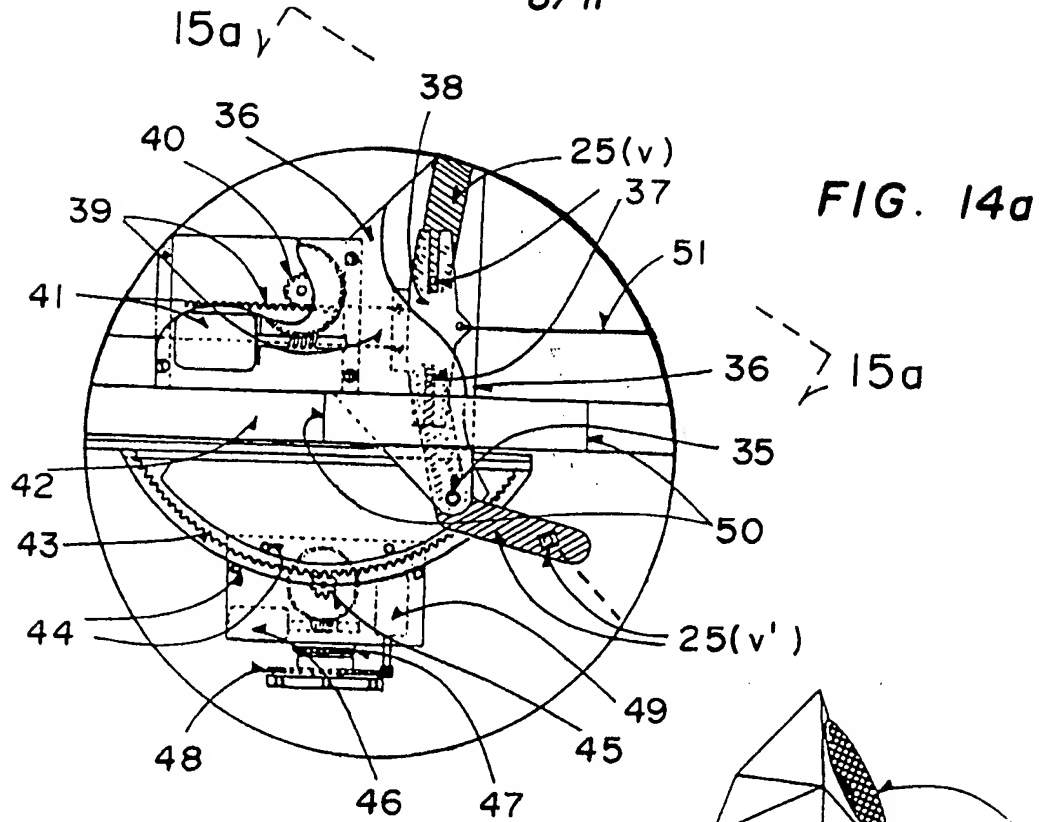
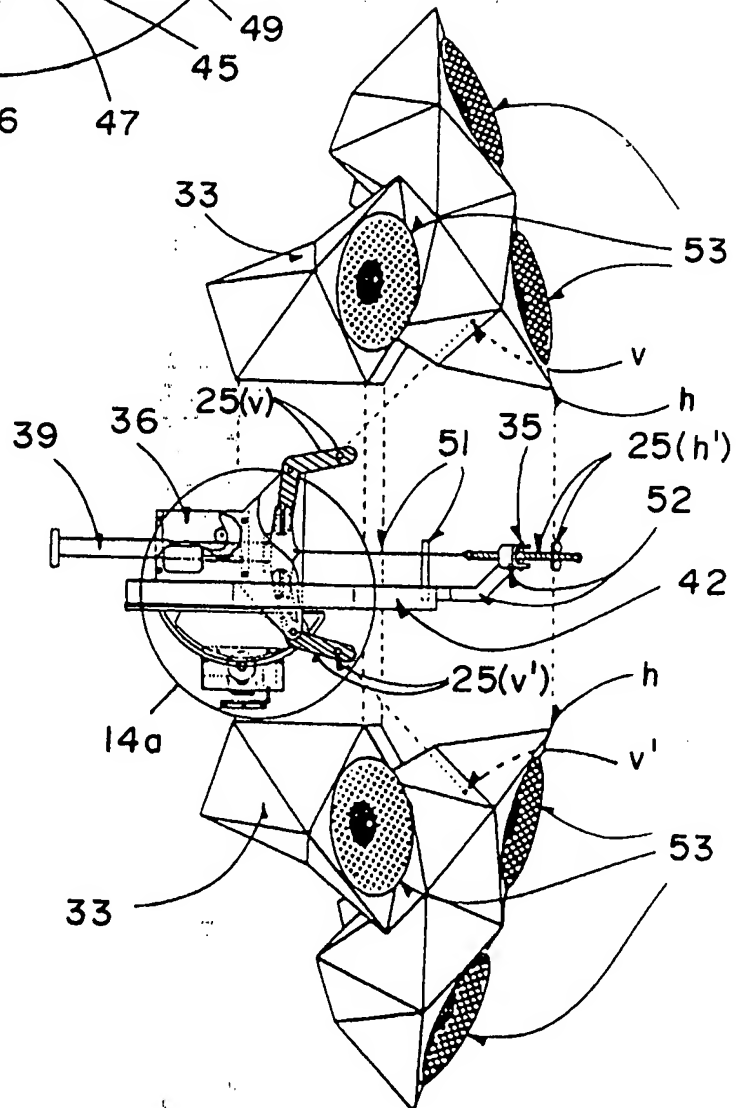
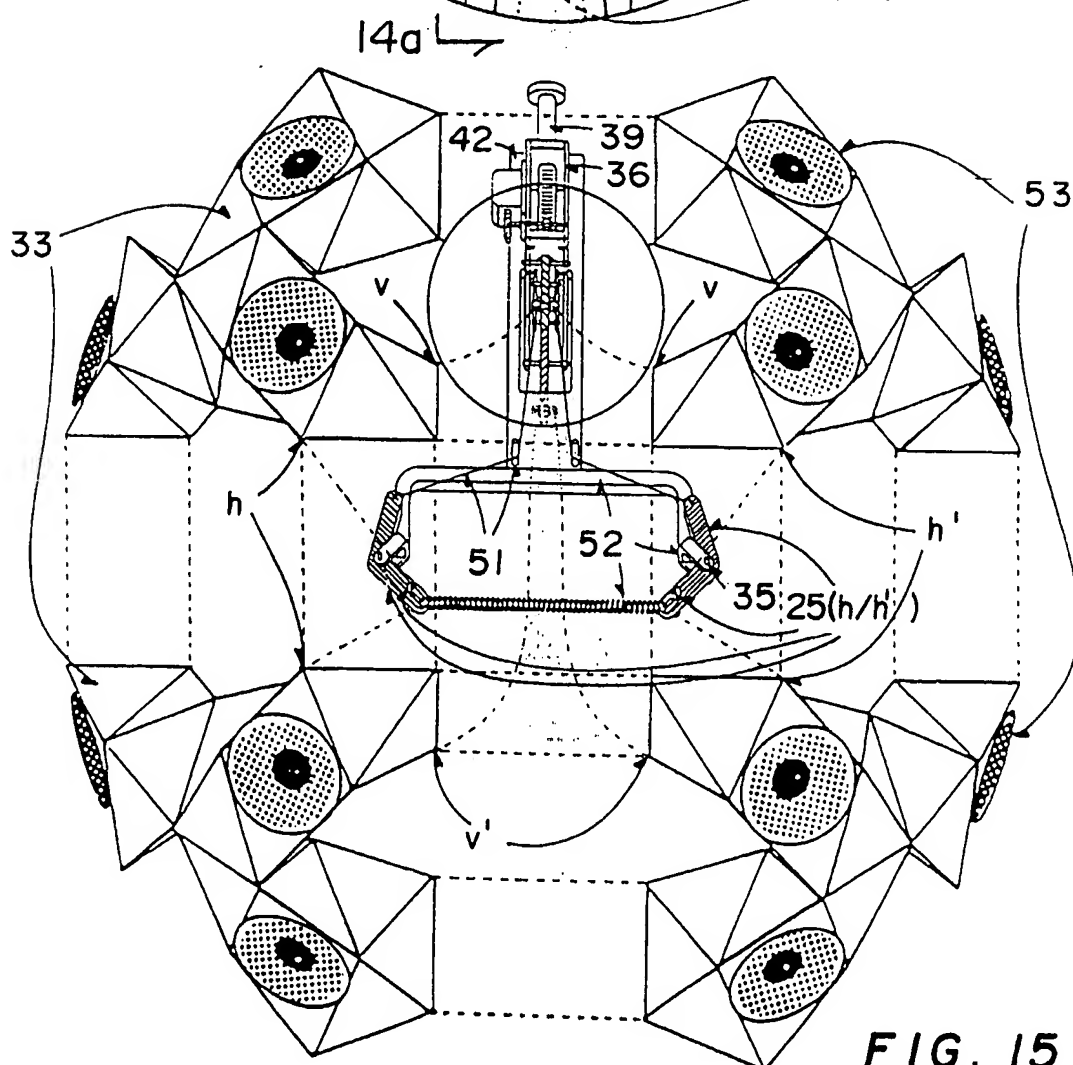
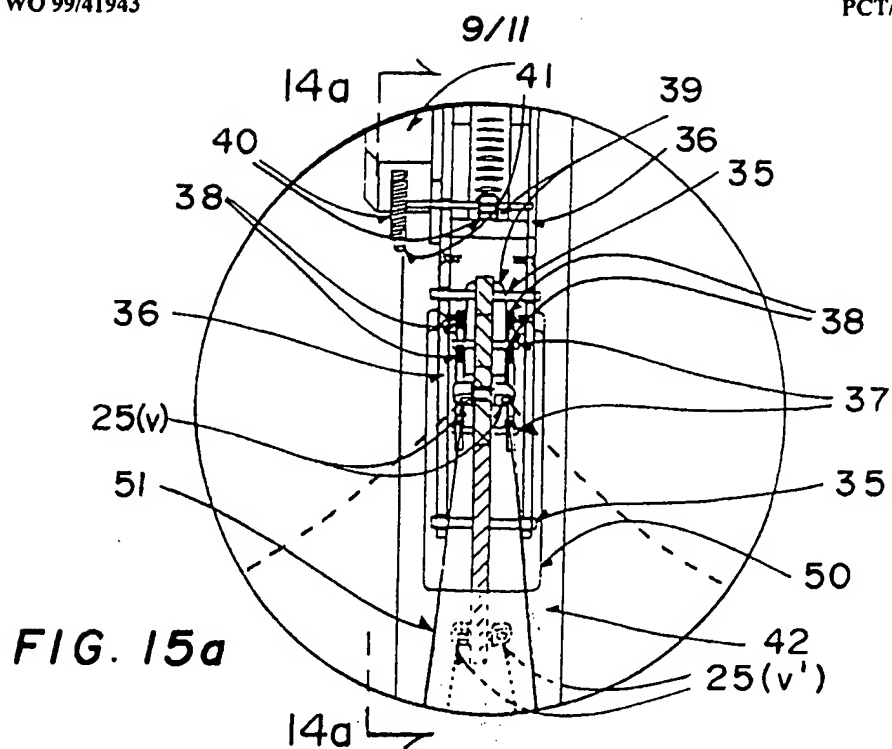


FIG. 14





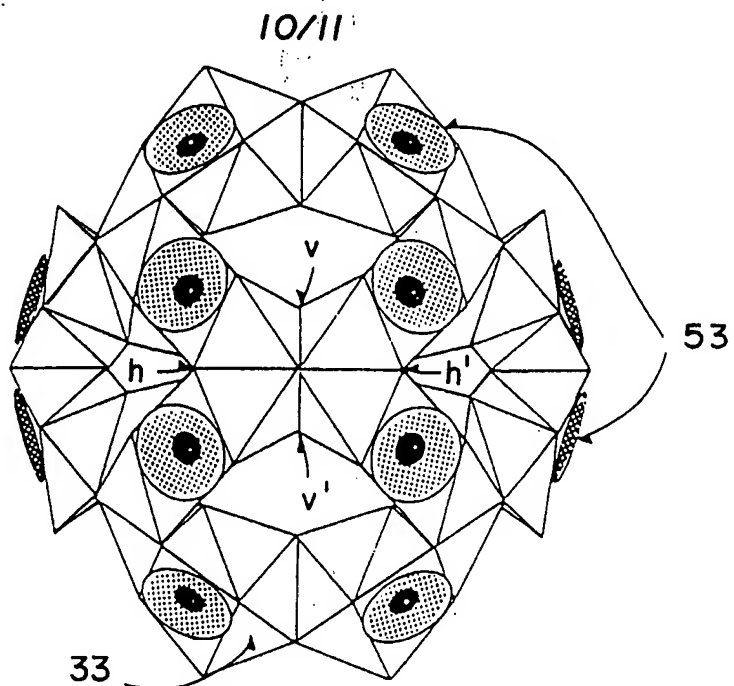


FIG. 16

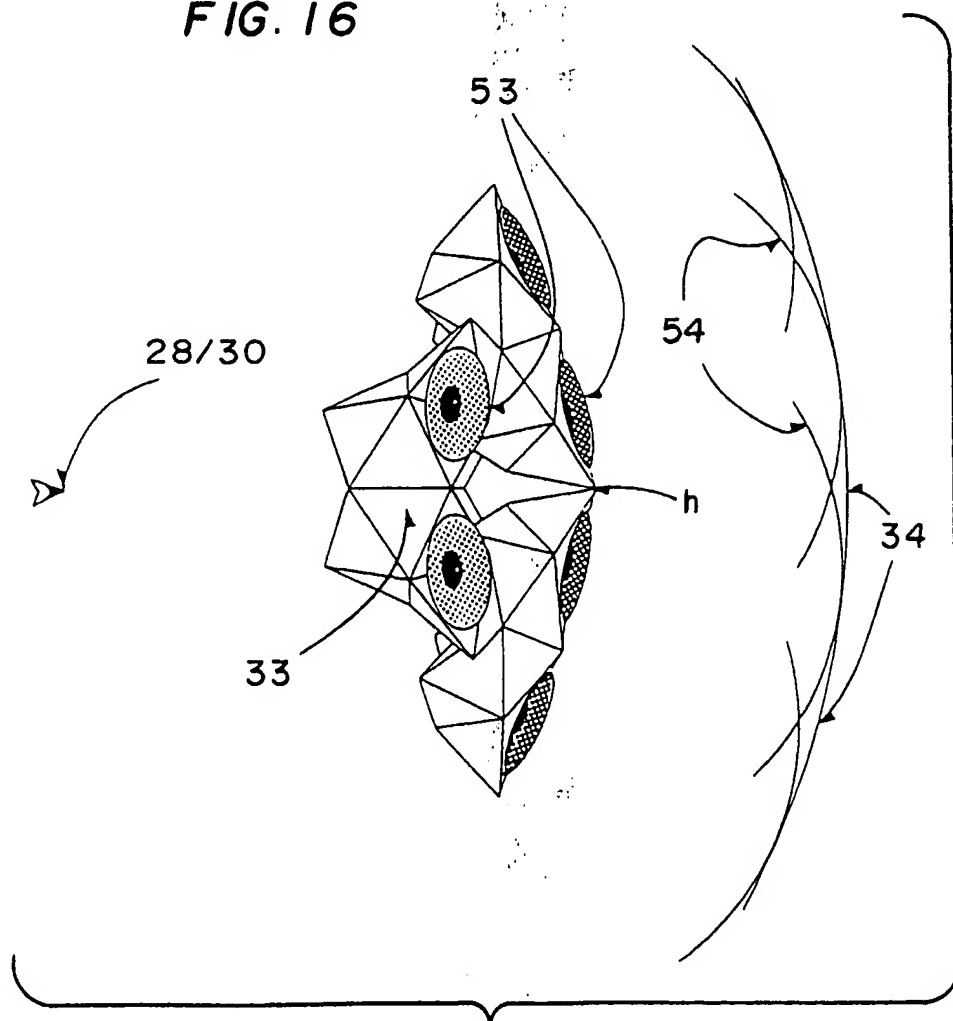
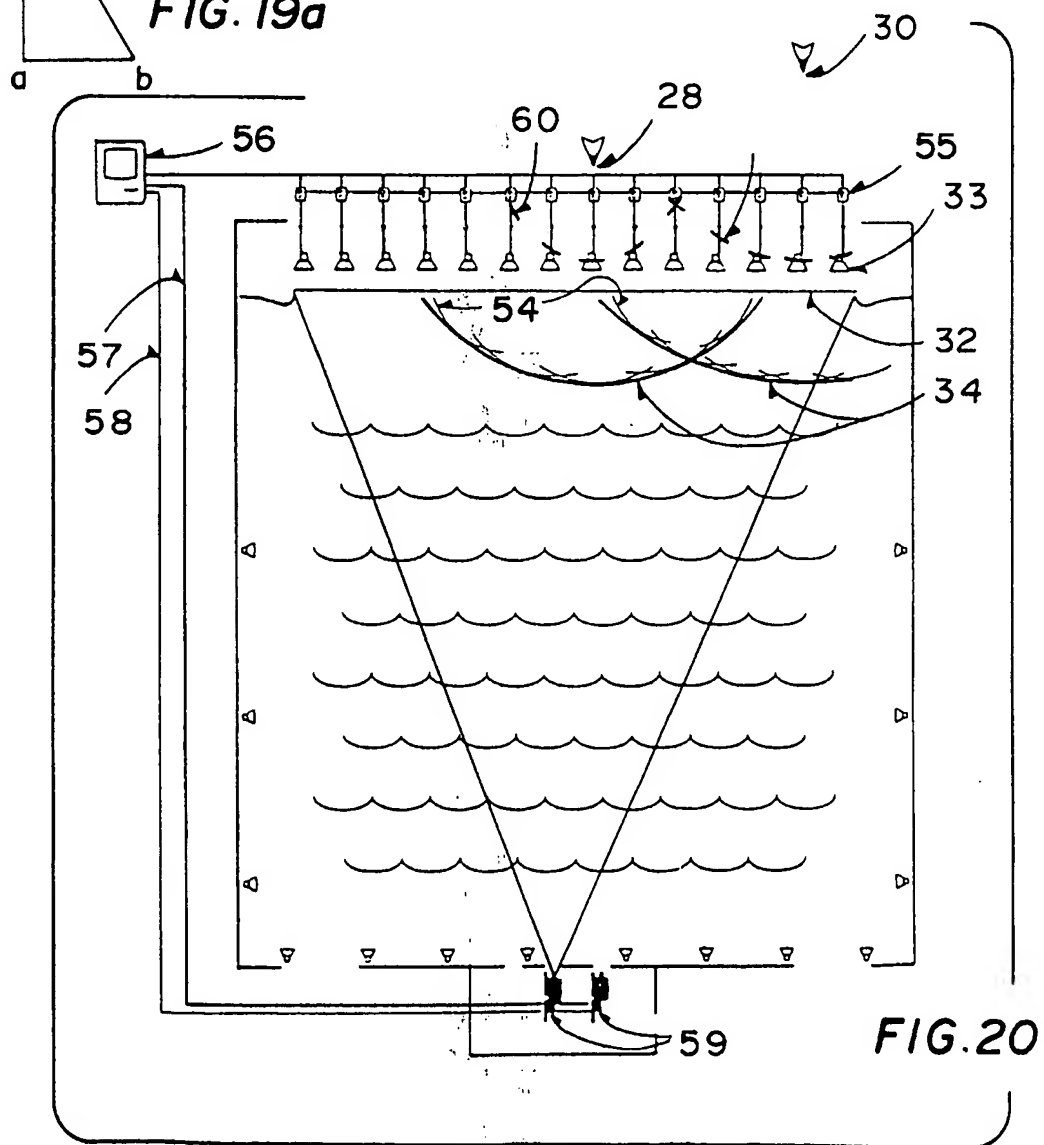
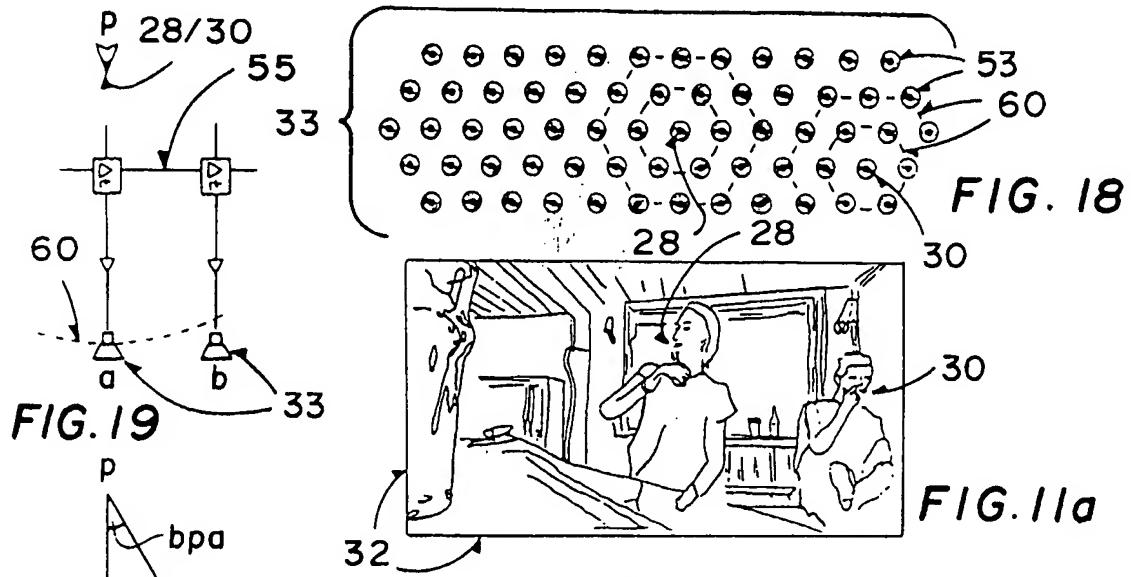


FIG. 17

11/11



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/01479

A. CLASSIFICATION OF SUBJECT MATTER IPC(6) :H04R 25/00 US CL :381/386; 248/370, 371 According to International Patent Classification (IPC) or to both national classification and IPC														
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) U.S. : 381/386, 395, 87; 248/370, 371, 161; 181/141, 199 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched NONE Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) NONE														
C. DOCUMENTS CONSIDERED TO BE RELEVANT														
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.												
A	US 4,753,408 A (WAILES) 28 June 1988, see figure 1.	1-2												
A	US 3,226,077 A (KILLEN) 28 December 1965, see figure 1	1-2												
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.														
<table border="0"> <tr> <td>* Special categories of cited documents:</td> <td>*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</td> </tr> <tr> <td>*A* document defining the general state of the art which is not considered to be of particular relevance</td> <td>*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</td> </tr> <tr> <td>*E* earlier document published on or after the international filing date</td> <td>*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</td> </tr> <tr> <td>*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</td> <td>*A* document member of the same patent family</td> </tr> <tr> <td>*O* document referring to an oral disclosure, use, exhibition or other means</td> <td></td> </tr> <tr> <td>*P* document published prior to the international filing date but later than the priority date claimed</td> <td></td> </tr> </table>			* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	*A* document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	*E* earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*A* document member of the same patent family	*O* document referring to an oral disclosure, use, exhibition or other means		*P* document published prior to the international filing date but later than the priority date claimed	
* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention													
A document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone													
E earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art													
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*A* document member of the same patent family													
O document referring to an oral disclosure, use, exhibition or other means														
P document published prior to the international filing date but later than the priority date claimed														
Date of the actual completion of the international search 28 APRIL 1999		Date of mailing of the international search report 19 MAY 1999												
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230		Authorized officer HUYEN LE <i>Huyen Le</i> Telephone No. (703) 305-4844												

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/01479

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-6

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/01479

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING

This ISA found multiple inventions as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I, claims 1-6, drawn to a frame of a structure unit.

Group II, claims 7-15, drawn to a loudspeaker with phase control.

The inventions listed as Groups I and II do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: Groups I and II have different technique features, the search required for Group I is not required for Group II.